THE PRINCIPLES AND PRACTICE OF ASEPSIS

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from Dr Colin Roderick
1964

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23/6/21

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1905

PREFACE

THE aim of the author of this volume has been to describe a practical and efficient system of asepsis. It is not possible to do this, however, without stating the scientific principles upon which such a practice must be based.

Aseptic surgery does not consist in a series of procedures mechanically performed, but needs a just appreciation of the exact reason for every action, however apparently trifling it may be.

Some writers have objected to aseptic surgery on the ground that it causes every operation to become a bacteriological experiment. No greater praise could be given to such a system, for every surgical procedure is a bacteriological experiment, whether the surgeon chooses to call it one or not.

The opposition to aseptic surgery which is still found in certain writers is partly due to an imperfect knowledge of bacteriology, and partly to that trait in human nature which impels us to follow the least troublesome road.

In surgery, however, the apparently easy path

is liable to prove the most difficult and dangerous in the end, whereas the consistent practice of asepsis becomes constantly easier as aseptic habits become a second nature.

The author has tried to lay especial stress upon three points which are often neglected in works of this kind. The first is the importance of conserving tissue resistance; the second is the advisability of avoiding contamination of the hands with microbes of high virulence; the third is the extreme difficulty of sterilizing organic substances such as catgut. With regard to the latter, the author has ventured to add another to the many methods already proposed for sterilizing gut. After twelve months' trial it has given absolute satisfaction, and it is given in the hope that those who have hitherto been satisfied to disinfect their catgut by the agency of chemicals may be induced to use heat instead.

With regard to the literary aspect of the work, the author has tried to make every sentence simple, plain, and unequivocal, and to absolutely eliminate 'padding' of any kind whatsoever.

A. S. V.

SYDNEY,
December, 1904.

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INTRODUCTION

In my opinion Dr. Vallack's work on the Principles and Practice of Asepsis is a useful addition to the literature of this most important subject. In it the busy practitioner will find the views of the most successful operators expressed in a succinct and readable form, and by following the rules therein laid down he will be able to perform operations himself with a success unattainable by purely antiseptic methods. The most important facts clearly brought out in this work appear to me to be that it is impossible by any known method to render hands which have been already contaminated with septic matter pure, and that therefore it is necessary to cover them with sterilized rubber gloves. Not only is such a protection advisable during an operation, but, as I think Kocher was the first to point out, it

is even more important at other times, and especially when dealing with evidently septic material, such as sloughing cancers and inflamed or suppurating wounds. Such a practice is simply a carrying out of the generally acknowledged principle that prevention is better than cure.

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58, Merrion Square,
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January, 1905.

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INTRODUCTORY

It is not advisable in a work of this character to enter to any greater extent than is absolutely unavoidable into the domains of pathology and bacteriology. Before proceeding to the study of practical surgery the student should be conversant with these sciences. Therefore at the outset the assent of the reader is asked to the following axioms. Upon these foundations the whole structure of aseptic surgery rests.

I. In surgical practice microbes are the sole cause of suppuration. No wound can secrete any pus whatever unless microbes be present in it.

II. If microbes be introduced into a wound, the result, as regards suppuration, depends upon three factors alone :

1. The number of organisms introduced.

2. The virulence of these organisms.
3. The resisting power of the tissues towards the organisms introduced.

III. The above statements apply, not only to suppuration, but also to erysipelas, cellulitis, wound diphtheria, spreading traumatic gangrene, and anthrax, when these attack a wound. They also apply to sapræmia, septicæmia, pyæmia, and tetanus, when these result from the infliction of a wound.

In actual surgery the first axiom scarcely comes under consideration, because practically no operation is ever performed without the introduction of some organisms into the wound. Therefore the three objects which the surgeon seeks to attain are :

I. To introduce as few organisms into the wound as possible.

II. To avoid the introduction of germs of high virulence.

III. To maintain the resisting powers of the tissues at as high a standard as possible.

It is possible by careful attention to these rules to insure that practically every wound inflicted by the surgeon upon aseptic tissues will heal by first intention. The majority of

surgeons attend more or less strictly to the first rule, but the second and third do not receive the attention which they merit, yet they are of quite equal importance.

For the purposes of this work it will be more convenient to consider these three propositions in a reverse order. After having done this, the treatment of septic wounds and accidental wounds will be considered.

PART I

TISSUE RESISTANCE

It cannot be too strongly insisted upon that the healing of every wound and the recovery of every sick person are due to the reparative power of the tissues alone. The surgeon and the physician are not the agencies whereby recovery is brought about ; their function is to aid, when able, the tissues in their struggle. The vast majority of micro-organisms are quite unable to attack living tissues ; on the contrary, the tissues are quickly able to exterminate them. On the other hand, some are of such high virulence that when introduced even in the smallest quantities into living tissues they are able to successfully attack them. Between these two extremes are a multitude of organisms which can overcome tissues when resistance is low, but not when it is high. Organisms which can attack living tissues are termed parasitic, those which only live on dead matter are termed saprophytic. Organisms which are

usually saprophytic, but sometimes attack living tissues, are called facultative parasites. Even where tissues are at first overcome they are often able in the end to successfully resist and destroy the invader. This effect is brought about by the production of certain chemical substances termed bacteriolysins, which are able to destroy the microbes. Their appearance is often preceded or accompanied by the production of substances able to cripple and inhibit them (agglutinins), and others which can neutralize the poison produced by the bacteria (antitoxins). As yet we have not been able to produce these substances artificially to any great extent, but the antitoxin of diphtheria is of very great value. The antistreptococcic and other anti-sera are of more doubtful utility. Bacterial vaccines are on their trial for the cure of chronic local infections. It is possible that in the future the use of these antibacterial agencies may prove of great importance, especially with regard to prophylaxis, but at present the investigations have been of no great practical value in increasing tissue resistance or lowering bacterial energy.

Of course, if a wound were absolutely free from germs, any lowering of tissue resistance would be of little consequence; but in practice it is impossible wholly to avoid contamination

of wounds with organisms capable of becoming parasitic.

General Causes which Lower Tissue Resistance.

These are :

1. Disease.
2. Starvation and bad hygiene.
3. Cold.

Any disease of a debilitating nature lowers tissue resistance. Diabetes is a notable example of this. Hence diabetics readily succumb to any tissue infection. Even in the milder forms of the disease the question of operating becomes a serious one. Bright's disease is less serious in this respect than diabetes, but if at all advanced it is advisable, if possible, to avoid operation. All patients should have their urine tested before the question of operation is considered. Cancerous cachexia, heart disease, with broken compensation and nerve diseases, accompanied by trophic disturbance, are amongst the common causes which lower tissue resistance. Alcoholism and the morphia habit also greatly impair the vitality of the tissues.

Contrary to what might be expected, old age has but slight influence upon tissue vitality if the organs be otherwise healthy. Young children, on the other hand, have not such good

resisting power as adults, especially to pyogenic cocci. Nevertheless, a surgeon who has confidence in his aseptic precautions should not hesitate to operate upon the youngest child.

Starvation, either by reason of quantity or quality of food, obviously lowers tissue resistance, as do also bad ventilation, overcrowding, and bad sanitary conditions. In these cases it is often advisable to place the patient upon good diet and amidst healthy surroundings for a period of time before submitting him to operation.

Cold is a factor of importance in lowering tissue resistance ; nor is this importance merely theoretical, but has a practical bearing upon surgical treatment. Pasteur found that fowls, which are naturally immune to anthrax, could be rendered susceptible to it by immersion in cold water. In dogs it is possible to induce septic peritonitis by filling the peritoneal cavity with cold sterile water ; the lowering of vitality enables organisms to pass through the walls of the gut. The patient should be kept warm during and after an operation, not only with the idea of lessening shock, but also of combating sepsis. The air of the operating-room should, if possible, be kept warm, especially when large surfaces are exposed, as in abdominal section.

Local Conditions which Impair Tissue Resistance.

These may be divided into two groups :

1. Causes which are outside the wound.
2. Causes which are within the wound.

The chief causes outside the wound are interference with blood-supply and interference with nerve-supply.

Interference with blood-supply is an obvious reason for lowered tissue resistance. I am convinced that for practical purposes the freedom of venous return is of more importance than the abundance of arterial supply. We see that quite bloodless tissues, such as the cornea, heal readily, as do also tissues which have naturally a poor blood-supply, such as tendons and fasciæ. The ease with which wounds of the head and face heal is probably quite as much due to the facility of venous return as to the richness of arterial supply. On the other hand, the difficulty of healing found in the legs and feet is due to the difficulty which the blood has in leaving them. Thus, raising the lower extremities increases tissue resistance by favouring venous return.

Impairment of nerve-supply greatly lowers tissue vitality. The nerves have a most important trophic influence over all tissues, and

where the nerve-supply of any part is interfered with organisms will be more likely to make a successful attack.

Local conditions within the wound which impair tissue resistance are naturally of the utmost importance, and it is necessary that the surgeon should leave the tissues with their vitality as little interfered with as possible. Rough manipulations should be strictly avoided. Tissues should be evenly divided with a sharp knife, and when tearing is used, either by means of the fingers or blunt dissector, it should be strictly confined to natural lines of cleavage. Especially should the abdominal viscera be handled with great gentleness ; they should be coaxed rather than forced. Where vessels are tied, no more tissue should be included in the ligature than is absolutely necessary. All bleeding should be stopped before the wound is closed, and by means of buried sutures all spaces should be obliterated, so that no blood-clot may collect in them. If this be not practicable the wound should be drained. Sutures must not be tied any tighter than is necessary to bring the tissues into moderately firm contact. Making sutures too tight is a common surgical error. By careful attention to these details and common cleanliness, a surgeon will often obtain better results than a colleague who is perhaps

needlessly particular in unimportant details of asepsis. In this way ridicule may be thrown upon the efficacy of asepsis itself. Asepsis, however, like religion, should not be judged by the performances of some of its advocates. It is the tissues, and not the surgeon, who achieve the process of healing, and the man who should be their friend and helper is sometimes their worst enemy. To maintain the vitality of the tissues is as much a part of asepsis as to diminish the number and virulence of the germs which enter a wound. Microbes which have overcome tissues of low resistance may have their virulence so increased thereby that they may proceed to attack healthy tissues.

PART II

WOUND INFECTIONS OF HIGH VIRULENCE

The virulence of micro-organisms varies within very wide limits. There are many organisms which are incapable of becoming pathogenic under any circumstances. Others, such as the *Streptococcus erysipelatis*, are capable, even when introduced in the minutest quantity, of setting up very severe tissue infection. A germ of high virulence may be defined as one which is capable of setting up an acute inflammatory disturbance, or of causing severe constitutional symptoms, when introduced in small quantity into tissues of normal vitality. Not only do microbes of different species vary immensely in virulence, but there is a wide range in this respect between organisms of the same species. We do not fully understand the factors which cause this variation, but it is certain that the virulence of an organism is, as a rule, exalted by a successful attack upon the tissues. For

example, the *Bacillus coli communis* in its normal situation in the bowel is not an organism of high virulence. Wounds of the rectum, as a rule, heal readily. If the bacillus, however, should make a successful attack upon diseased or injured tissues, its virulence becomes much increased, and it may then become capable of attacking healthy tissues. The same phenomenon has been observed in the case of other organisms, and is perhaps a universal rule.

I am convinced that a considerable majority of the more acute and dangerous wound infections are due to inoculation with organisms which have been derived from a previous case of a similar nature. I believe, further, that in most of these cases the infection is carried directly from one patient to another. We all recognise that such was the case before the days of antiseptic surgery, but many do not recognise the serious danger of this happening at the present day. The reason of this false sense of security is the mistaken idea that the hands can be rendered free from germs. If, then, these infections are so conveyed, it should be easy to discover what are the means by which this may take place. Of all the objects which come into contact with a wound, only three are likely to have come into direct relationship with

previous cases of tissue infection. These three are :

1. The hands of the surgeon or his assistants.
2. Instruments.
3. Sponges.

Besides these, two other possible sources suggest themselves :

4. A septic lesion in the patient himself.
5. Infected catgut.

Hands are probably by far the commonest source of acute wound infections at the present day. If once the fingers have become contaminated by pus or other virulently infective material, it is impossible to tell when they will become free from infection again. In the meantime every wound touched by them may cost a patient his life. It is therefore of extreme importance that the surgeon should strictly avoid contaminating his hands with any such. Fortunately, by the use of rubber gloves it is easy to avoid contamination. The surgeon should always put on rubber gloves before touching any case of severe tissue infection, such as abscess, cellulitis, inflamed wound, or any suppurating or infective focus. Even after the inflammation has disappeared, the skin near such a lesion abounds in virulent germs. The introduction of the hand into a rubber glove may be greatly facilitated by soaping the hand.

The assistant surgeons and nurses at all operations should wear sterilized rubber gloves, in order that infection of any kind from their hands may be avoided. Of course, the safety as regards infection will be increased if the operating surgeon himself wear gloves, but there can be no doubt that they hamper him more or less seriously in operations requiring a delicate manipulation.

If he operate in aseptic cases with bare hands, he should certainly never touch with unguarded fingers any case which has the faintest suspicion of being septic. The surgeon who follows these directions and uses even moderate aseptic precautions will have a lower mortality than he who practises the most elaborate asepsis, but neglects these rules.

The frequency with which accidental wounds heal by first intention is evidence that the micro-organisms found upon the skin are not often of a highly virulent nature, and are, as a rule, incapable of setting up an acute inflammation, where the vitality of the tissues has not been seriously interfered with. But an indefinitely small number of organisms from a case of acute cellulitis planted in the wound by the surgeon's or assistant's fingers may rapidly lead to a fatal issue. Yet in many hospitals the house-surgeon is allowed to dress suppurating

wounds with his bare hands in the morning, and to assist at operations in the afternoon.

The great difference in virulence between organisms from a case of acute sepsis and those found upon the hands even of dirty persons is well shown by midwifery practice. It is a common thing to see an ignorant midwife, with hands of the dirtiest description, attend parturient women without the slightest harm resulting. Even when infection takes place, it is as a rule of low virulence, and ends in recovery. If, however, a case of acute puerperal septicæmia occur in the practice of such a woman, she will probably soon convey a fatal infection to a number of other persons. Custom has very wisely relegated the practice of midwifery to physicians rather than to surgeons, otherwise our mortality from puerperal fever would be even more deplorable than at present. I have known the most scrupulous accoucheurs to infect their patients with fatal sepsis derived from previous cases of tissue infection. Those who attend midwifery cases should exercise the same care as the surgeon with regard to infecting their hands with germs of high virulence.

A second possibility of acute infection from the surgeon's hand may arise from there being upon it a suppurating focus or inflamed

sore. In this case the surgeon has no choice but to wear rubber gloves when operating. A rubber finger-stall is not sufficient, for pus germs have probably become distributed about the skin of his hands.

Instruments at the present day are a much less frequent source of severe wound infection than hands.

With regard to the convection of acute wound infections, they may be divided into two classes —viz., those which will stand boiling and those which will not. With regard to the latter, it is preferable to destroy such as have become contaminated with germs of high virulence. Instruments which can be boiled may be disinfected with ease and certainty, provided that their construction is such that the boiling water may come into contact with every part of them. The importance of this will be dealt with in the next part of the work.

Sponges are a possible source of severe wound infection.

Schimmelbusch is satisfied that sponges may be absolutely disinfected by boiling soda solution, as will be subsequently described. This statement, coming from so high an authority, must carry great weight; but, nevertheless, the majority of surgeons would prefer to be on the safe side by destroying such sponges as had

become impregnated with organisms of high virulence.

The patient himself may be the source of an acute wound infection by reason of a focus being present in his own body. Thus it is of importance to see that no suppurating lesion, however insignificant, exists in the neighbourhood of the area to be operated upon. Even so small a thing as a suppurating hair follicle may lead to serious results. It is preferable, therefore, to defer operation until such lesion is cured; but if operation is imperative and any fear of contamination exist, it is better to drain the wound and to avoid the use of buried sutures. Even where the patient has a suppurating focus in some distant part of his body, it is always possible that he may convey virulent germs to the area to be operated upon by means of his fingers.

Catgut must be regarded as a possible source of acute infection. Being made from the gut of the sheep, it may be contaminated, not only with the germs which abound in the intestine of the animal, but also with far graver infection. There appears to be little doubt but that anthrax has been caused by the use of gut from sheep suffering from this disease.

The mode of disinfecting gut will be dealt with in a later part of this book.

PART III

THE ASEPTIC TREATMENT OF OPERATION WOUNDS

SECTION I.—Introductory.

IN their normal state all tissues except surface tissues are in an aseptic condition. It is evident, then, if germs are found in a wound, that they have been introduced by some substance which has come into contact with the wound. A complete list, therefore, of all the substances which come into contact with the wound would include all possible avenues of infection. Such a list includes :

1. Air.
2. Patient's skin or mucous membrane.
3. The hands of surgeon and assistants.
4. Instruments.
5. Water and lotions.
6. Sponges.
7. Swabs, dressings, towels, surgeon's and assistants' coats.
8. Ligatures and sutures.
9. Drainage apparatus.

In every case of wound infection one of the above must be at fault. It is necessary, therefore, to inquire in each case as to what means can be used to prevent infection.

Section II.—Infection from Air.

At first sight it would seem that air might prove an important source of wound infection.

It is a matter of common observation that exposure to air soon brings about putrefaction in organic matter, and the statement that air contains so many thousands of micro-organisms to the cubic metre sounds rather alarming. As a matter of fact, however, both scientific experiment and clinical experience show that air is of little or no importance as an agent in contaminating wounds. Schimmelbusch showed that in Von Bergmann's operating theatre, even when the students were present, only from sixty to seventy germs were deposited upon a culture-plate 1 square decimetre in size in the course of half an hour. It has also been repeatedly shown that amongst the microbes so deposited exceedingly few possess any pathogenic properties. For example, Cleves Symmes, who experimented in the surgical wards, found that out of 4,613 organisms deposited upon culture-plates only a single one was pathogenic—viz., *Bacillus pyocyaneus*. Not a single pus coccus

was found. Thus, from these two experiments we see that the chance of even a single virulent germ entering a wound from the air is a remote one. It is so remote, indeed, that with ordinary care it may be ignored. All draughts or active air currents in the operating-room should be avoided, the accumulation of dust should be prevented, and care should be taken that the room be not swept within several hours before the time of operation, so that any dust stirred up thereby may have ample time to settle.

There is, however, another source of air-borne infection which cannot be so easily ignored, and that is infection from the mouths of those in immediate proximity to the wound. In the act of speaking, fine particles of saliva are thrown into the air which contain organisms. Although the majority of such are comparatively harmless, yet they may not always be so, especially if carious teeth or other septic conditions prevail in the mouth of the speaker. It is advisable, therefore, for those who are near the patient to speak only when necessary, and in a low tone, and not to direct the mouth towards the wound in speaking. It is also advisable that they should avoid carious teeth or other conditions of oral sepsis. Coughing or sneezing in the direction of the wound are likewise to be avoided.

Section III.—Sterilization.

Owing to the universal distribution of germs, every object must be regarded as bearing germs upon it. Hence every object, before being brought into contact with a wound, must be *sterilized*—that is, rendered free from living germs or spores. In the case of living substances such as skin or mucous membrane, sterilization can only be comparative—that is to say, the number of germs upon them should be reduced to as near the vanishing-point as possible. In the case of dead or inorganic substances sterilization can and should in every case be absolute ; that is to say, they should be entirely freed from living germs. Sterilization or disinfection is brought about by the use of three classes of agencies :

1. Mechanical.
2. Physical (*i.e.*, heat).
3. Chemical.

The mechanical means include washing, scrubbing, and shaving, and also the application of solvents for grease, etc., such as ether or turpentine. The importance of careful and thorough mechanical cleansing cannot be overestimated. In the case of skin and mucous membrane disinfection is chiefly a mechanical process, and even in the case of objects which

can be sterilized by heat, especially where moist heat is used, mechanical cleansing is still absolutely indispensable. Whether boiling water, steam, or chemicals be employed for the destruction of microbes, it is necessary that the germicidal agent should come into actual contact with them. Chemical antiseptics have but slight power of penetrating grease, dried pus, or blood, nor is the power of steam much greater in this respect. If boiling water or steam do not come into contact with the germs, the heat must be counted as dry heat. This is a most important distinction. Septic matter in the lock of an instrument may not be reached by boiling water, and steam will not readily penetrate dirt or grease. In such cases disinfection may be a matter of hours instead of minutes.

The physical means consist in the application of heat. Heat is by far our most reliable disinfecting agent, and if combined with moisture its efficacy is greatly increased. The moisture may be either in a fluid or gaseous state, the action in the former case being much more rapid.

Boiling water is our most reliable and most rapid means of destroying bacteria. If brought into contact with most forms, it will destroy them in a few seconds. There are a few germs which will resist boiling for a considerable time.

The most resistant of ordinary pathogenic germs is the spore of the anthrax bacillus. In all experiments regarding the efficacy of disinfectant measures this should be taken as the standard. If any given method will destroy with certainty the spores of anthrax, it will also with certainty destroy any ordinary pathogenic germ. Unfortunately, anthrax spores themselves vary in their powers of resistance, but it is well within the truth to say that fifteen minutes' boiling will with certainty kill them, provided that the water can penetrate to the spores themselves. When boiling water is used to disinfect metal objects, it is usual to add $\frac{1}{2}$ per cent. of carbonate of soda to prevent rusting, but for this purpose $\frac{1}{2}$ per cent. of lysol is superior, and keeps them in better preservation. Boiling, then, is the method of choice for purposes of sterilization, and should be used in all cases where no objection to it exists. It is employed for all metal objects such as instruments, also for nail-brushes, rubber goods, silkworm gut, silk, and horsehair. With the two last-named pure water should be used, as alkali rots them. Boiling is also used to sterilize water and various solutions.

Scalding is sometimes useful in an emergency, where time is lacking or suitable apparatus for

boiling is wanting. The instruments are placed in a deep tray or basin, and boiling water is poured upon them till they are well covered. By this means common pathogenic germs, such as pyogenic cocci, are killed.

Steaming is next to boiling in efficiency. It should be employed for cotton and linen goods, which are required to be comparatively dry when used at operations. It is absolutely essential that all objects to be sterilized by steam should be clean, as it will not penetrate grease and dirt. Steam at 100° C. will kill anthrax spores in less than twenty minutes. This method is used for the disinfection of such materials as dressings, bandages, towels, linen coats, and aprons. For this purpose a specially constructed chamber is used. The essentials of a steam sterilizer are that it should be capable of maintaining a temperature of 100° C., and that the steam should enter at the highest part of the chamber and leave it at the lowest. This greatly increases its penetrating power. As steam is lighter than air, the latter sinks to the lower part of the chamber, and is forced out. Whilst these are the essentials, certain other properties are advantageous. If means are present to warm the materials before the steam reaches them, much less moisture will be deposited upon them. The disinfection is made

more rapid if the pressure of the steam can be raised. The apparatus of Lautenschläger is one of the best. In this the steam chamber is surrounded by a water-jacket, and it is by boiling the water in this jacket that the steam is produced. Thus the chamber and its contents are warmed before the steam enters, and condensation to a large extent prevented. Such an apparatus can be relied upon to effectually sterilize within forty minutes, reckoned from the time when the temperature within it rises to 100° C. The towels, etc., must not be too tightly folded, nor must the contents be packed too tightly together, or the steam may have difficulty in penetrating.

When once dressings are sterile they may be preserved so for an indefinite time, provided that they are kept in a sterile and air-tight case. For this purpose the case invented by Schimmelbusch is of value. It is made of metal, and has a number of perforations for admitting the steam. These can be closed by a simple mechanism when sterilization is complete.

Hot air has been used as a means of disinfection, but for this purpose it is conspicuously inferior to steam. Not only is its disinfecting power much less, but it is a most difficult thing to maintain an equable temperature in the interior of a dry chamber. Hot air has been

used to sterilize catgut by Reverdin. After careful drying, the gut is exposed to a temperature of 140° C. for three hours. The process is difficult in technique.

Dry heat in a liquid medium, such as alcohol, xylol, or cumol, is much easier to control, and is a valuable means of disinfecting catgut. In using such substances the heat must be strictly regarded as dry heat, and the temperature must be very high or the exposure prolonged. Probably in all cases exposure for six hours at a temperature of 100° C. would affect sterilization. Much higher temperatures, however, may be employed. I have heated catgut in creosote to 200° C. without injuring it.

Sterilization by chemicals was the first method to be used for the destruction of germs. In the early days of the antiseptic era great importance was attached to the bactericidal action of certain chemical substances. At the present day these bodies have been relegated to the least important position in the prevention of wound infection. This is due to the discovery that the efficacy of antiseptics has been much overestimated, and also to a due realization of their injurious effects upon the tissues of the body. How injurious these are is shown by the fact that the hypodermic injection of a solution of perchloride of mercury is liable to set up

suppuration by enabling germs to attack the devitalized tissues. The exaggerated idea which once prevailed regarding the germicidal effects of chemicals was due to a lack of appreciation of the important distinction which should be made between the *inhibition* and the destruction of bacteria. A comparatively weak solution of many chemical substances will inhibit the growth of organisms, so long as it is kept in contact with them, but the prolonged application of a much stronger solution may be required to kill them. Thus, the growth of anthrax bacilli is prevented by 1 part in 300,000 of perchloride of mercury, but it takes a solution 300 times as strong a considerable time to kill their spores. Behring killed mice with anthrax which had been exposed to a 1 in 1,000 solution for half an hour. Many of the earlier experiments have been proved untrustworthy. Threads were impregnated with a culture of microbes ; these threads were placed in the antiseptic for a certain time, and then transferred to culture media. Because no growth took place it was assumed that the bacteria were dead. This fallacy was exploded by Geppert, who showed that in the case of corrosive sublimate, if total precipitation of the chemical were assured by adding sulphide of ammonium, the supposed dead germs grew

readily. Geppert clearly showed that results were valueless unless the antiseptic itself were totally destroyed before assuming that the microbes were dead. Yet subsequent observers have repeatedly fallen into error on this point. A piece of silk, catgut, skin, or other object is dropped into nutrient broth, and because no growth takes place they are presumed to be sterile. This assumption is not valid. Mere apparent dilution by placing the substance in a quantity of fluid nutrient medium may not suffice, for the chemical may be fixed by the substance, or even by the albuminous envelope which sometimes surrounds the bacteria themselves. That these facts are of great importance is shown by the difference between cultivation experiments and inoculation experiments. Thus, Klemm showed that catgut which would yield no growth in nutrient media, even when chopped and teased into minute particles, was nevertheless able to set up severe sepsis in cats when implanted into them with every aseptic precaution. That these precautions were efficient is shown by the fact that silk threads introduced under the same conditions healed in readily. Even inoculation experiments are not conclusive when negative unless the germs be of high virulence and the animal readily susceptible ; for bacteria so introduced may be

killed by the tissues. These considerations apply with much force in the case of catgut.

The exaggerated ideas which once prevailed with regard to chemical antiseptics is well illustrated by the case of carbolic acid. This was once held in high esteem as a germicide, yet a 5 per cent. solution will not kill anthrax spores in a month. Boiling water kills them in less than five minutes. Even in the case of corrosive sublimate Schimmelbusch states that if Geppert's precautions be carefully observed solutions of 1 in 1,000 cannot be relied upon to kill *Staphylococcus pyogenes* within ten or even fifteen minutes.

It is also of importance to remember that in artificial experiments the conditions are all in favour of the antiseptic. When bacteria are in their native haunts, covered by folds of skin, under nails, buried in epithelial débris, grease, or other organic matter, then the conditions are all against the antiseptic, which has often great difficulty in reaching them at all.

The majority of chemical antiseptics only act in the presence of water. Perchloride or carbolic are quite inert if dissolved in oil, vaseline, absolute alcohol, glycerine, etc. It is very problematical whether the addition of germicides to soap in any way increases its antiseptic value.

Another objection to many antiseptics is the fact that their action is abolished by the presence of organic matter, especially albuminous matter. For example, perchloride of mercury and permanganate of potassium are rendered inert by the presence of a comparatively small amount of organic matter, such as serum, blood, pus, or fæces.

A grave objection to the use of chemicals is the very irritating and injurious action which they exert upon the tissues. We have seen that a 5 per cent. solution of carbolic acid will not kill anthrax spores in thirty days, yet it will have a very injurious effect upon skin exposed to it for as many minutes, and will considerably irritate the deeper tissues in as many seconds. Any substance which would injure *Staphylococcus aureus*, for example, would injure the tissues infinitely more. Perchloride solution introduced into a wound could not possibly kill any pyogenic cocci in it, but would certainly injure the tissues. It is a matter of experience how greatly the serous discharge from operation wounds diminishes when the use of antiseptics has been abandoned. In a word, antiseptics lower tissue vitality, and thus prepare the way for invasion by micro-organisms, whilst it is doubtful whether they have any effect upon the organisms contained in a wound. Also,

whilst they injure the tissues, the tissues neutralize their antiseptic effect.

In aseptic surgery chemical antiseptics have no place except in the preparation of skin. Even here their utility may be disputed, but it is certainly our duty to give the patient the benefit of the doubt until the point is finally settled.

A multitude of substances have been recommended as antiseptics. Most of them may be classed under three headings :

1. The metallic group, such as salts of mercury, silver, and zinc.

2. The coal-tar derivatives, such as phenol, cresol, creasote, lysol, and creolin.

3. Certain oils, such as the oils of turpentine, cloves, mustard, and juniper.

Besides these several acids, iodine and its compounds and many other substances have their advocates. It is well to avoid a multiplicity of such. The following three can be recommended as amongst the best for the particular purposes for which they are employed :

1. Potassio-mercuric iodide.
2. Lysol.
3. Boracic acid.

Iodoform may perhaps be of value in the case of certain specific infections.

Potassio-mercuric iodide, commonly known as

biniodide of mercury, is perhaps the most powerful antiseptic known to us. Most experimenters agree that it is more effective than the perchloride. Potassio-mercuric iodide also has two other advantages over the perchloride: it is not so irritating to the tissues, and it is not nearly so easily destroyed by the presence of organic matter.

Lysol consists chiefly of substances of the cresol group. Its soapy nature renders it an excellent substance for cleansing purposes, and a good lubricant, whilst it has the valuable property of preserving steel instruments from rust. It is rather irritating to the tissues, and somewhat poisonous.

Boracic acid has little irritating effect upon the tissues. It is of value as a means of inhibiting germ growth, whether applied as a dry powder to the skin wherever sweat is likely to collect and decompose, or in solution in the form of fomentations, etc. Boracic acid is of little value as a germicide, but is useful as an agent for inhibiting the multiplication of organisms, especially saprophytes.

Iodoform is possibly of value in certain specific infections, such as tuberculosis and soft chancre. It has the disadvantages of possessing an objectionable smell, of being toxic if absorbed, and of occasionally causing

severe eczema. The smallest quantity applied to the skin of certain persons causes a severe reaction. How iodoform acts beneficially is not known, for it does not act as a germicide *in vitro* at all. Its beneficial effects have probably been exaggerated in the case of septic wounds. Its use in aseptic wounds is not only useless, but mischievous.

Section IV.—Disinfection of Skin and Mucous Membranes.

The skin abounds in micro-organisms. Here they are supplied with warmth, moisture, and organic matter, and therefore find ideal conditions for growth and multiplication. The majority of these germs are not pathogenic, and highly virulent germs are certainly not, as a rule, present in any great number. The majority of accidental wounds will heal by first intention if they are made by a clean instrument and there is no great crushing or laceration of the tissues. There are, however, as a rule, organisms present in the skin capable of setting up suppuration if conditions favour them. For example, if a thorn perforate the skin, and be left *in situ*, it will usually cause suppuration. If, however, it be extracted at once the puncture

rarely suppurates. An aseptic stitch may set up a stitch abscess, especially if it be tied too tightly, owing to invasion by organisms from the skin. It is therefore necessary that the skin should be very carefully prepared before operation, with the object of reducing the organisms upon it to the smallest possible number. As it is not possible by any means at our disposal to wholly banish them, especially in certain situations, it is advisable to keep the skin of the patient as far as is practicable from coming into contact with instruments, ligatures, and sutures, especially such of the latter as are left in the wound. The best practical method of achieving this is by stitching sterile towels to the patient's skin around the wound area, or by the author's method of stitching napkins to the edges of the wound itself. The importance of these manœuvres is considerable, especially in regions such as the groin, where it is particularly difficult to disinfect the skin, and in abdominal sections, where the viscera are laid upon the skin of the abdomen. The author's method is as follows : After the skin and subcutaneous tissue have been divided, two sterilized napkins are stitched to the cut edges of the skin, one on each side of the wound. Beyond the ends of the incision they are pinned together with sterilized safety-pins. If during

the operation the surgeon finds it necessary to prolong the wound these pins may be temporarily removed. In this way infection from the skin of the patient may be almost entirely eliminated. This method is especially advisable in situations where the skin is difficult to clean, or in emergency cases, where there is not time to properly prepare the surface. It takes up little time if a continuous stitch with long intervals be employed. The stitches are not removed until the surgeon is ready to sew up the skin. The use of these napkins is not intended in any way to replace careful disinfection of the skin. They are used as an additional safeguard. Many methods have been recommended for disinfecting the skin. This is in accordance with the law that the number of methods is in inverse ratio to their efficacy. The main points to bear in mind are :

1. That no method secures absolute efficiency.

2. That the mechanical part of any method is the more important.

3. That intelligence is required for the application of any method.

In a word, *thorough* mechanical cleansing is the *sine quâ non*.

The author uses a modification of Lockwood's method, which probably is as good as any other. It includes six stages :

1. Shaving.
2. Washing.
3. Scrubbing.
4. Removal of grease.
5. Washing with biniodide spirit.
6. Application of pad of biniodide spirit.

It is not necessary to prepare the skin the night before operation, as is sometimes done. It makes the patient uncomfortable and restless, and irritates the skin, if a pad soaked in antiseptic be applied all night.

The preparation of the skin should be commenced by shaving, which should be done in all cases, whether visible hairs are present or not, for some hair is present almost everywhere. It is next washed with hot sterile water and soap by means of a swab of wool or gauze. The water should be as hot as can be comfortably borne. It is important to clean the skin in this way before the nail-brush is used, for if this be applied to dirty skin it will itself be made dirty. When the skin has been cleansed in this way a second basin of sterile hot water is brought, and a sterilized nail-brush with soap is employed. The art of using a nail-brush is one learnt by care and experience. In some situations hard scrubbing may be used, in others only light brushing is permissible. The process should be continued for several minutes. It should not

be so severe as to injure the skin. Common yellow soap is the best to use, as it is made by the hot process, and therefore sterile.

The grease should next be removed from the skin by means of rubbing with sterilized swabs soaked in turpentine or ether. Turpentine is the cheaper and more effectual, but is more irritating, and should not be used in situations where the skin is tender. In the case of ether it is a saving of expense to use the cheaper kinds. This is followed by cleansing with Lockwood's biniodide solution. The formula for this is :

Potassio-mercuric iodide ..	1 part.
Water	250 parts
Methylated spirit	750 ,,

It should be applied by means of sterile gauze swabs, with which the skin is rubbed for about two minutes. The hardness of the rubbing varies with the situation. Finally, a pad of sterilized lint soaked in the same solution is placed upon the skin, and covered with sterile wool and a bandage. This is left until removed at the operation. No method of skin disinfection is absolute in its effects, but if the above be carefully and conscientiously applied, and the method of sewing napkins to the skin edges be used, infection from the patient's skin may be practically abolished. The epidermis may

be rendered almost free from germs. Unfortunately, however, microbes are present in the hair follicles, and in the sebaceous and sweat glands. These it is impossible to remove. Fortunately, the virulence of these organisms is slight if the skin be healthy. The person who disinfects the skin should wear rubber gloves during every part of the procedure except the shaving, and should wear them even then if he has recently touched any septic case. They not only increase the safety of the patient, but save the hands of the person who prepares the skin.

Mucous membranes are even more difficult to disinfect than skin. Chemical antiseptics are quite useless. In solutions of sufficient strength to be even of hypothetical value they would be damaging. This, however, is not so great a drawback to disinfection as the fact that mucous membranes cannot be subjected to the vigorous mechanical measures which may be applied to the skin. Soap and hot water and such scrubbing as can be effected by means of a mop or swab are our sole means of reducing the number of microbes upon them. Fortunately, in the absence of any inflammatory condition, mucous membranes are singularly free from germs of high virulence.

The mouth is the cavity most likely to contain such. Before operations upon the mouth, if time permits, it is advisable to remove carious teeth some days at least before operation, and immediately before operation to cleanse the mouth by rinsing well with a hot 1 per cent. solution of borax or bicarbonate of soda.

The stomach may be washed out before operations upon it unless gastric ulcer be present.

The rectum may be washed out by enemata of normal saline solution or simply boiled water or soap and water.

The vagina should be douched with hot water, and then thoroughly scrubbed out with well-soaped mops of wool or gauze, which should preferably be controlled by the fingers, and not by a sponge holder. This is followed by a second douching with hot sterile water.

The urethra always contains microbes. If the surgeon thinks it necessary he can wash it out with a back-flow catheter, which may somewhat diminish their number.

The bladder is normally aseptic. If it is in a septic state it should be repeatedly washed out with sterile water before operation.

Urine is normally aseptic, and very slightly irritating to the tissues. The disastrous effects of infiltration of tissues with urine are solely

due to the fact that the urine is septic in these cases. Aseptic urine can be injected into the subcutaneous tissues of animals in almost indefinite quantities without doing any harm. Septic urine is not only highly irritating, but in some cases highly toxic also. It is therefore important in all cases of operation upon the urinary tract to prevent, or at any rate check, the decomposition of urine by microbes. This can often be done, because, as has been shown before, although the destruction of bacteria by chemicals is a difficult matter, their inhibition is much easier. Certain substances taken by the mouth render the urine much more unfavourable as a culture medium. The best are those which cause the appearance of formic aldehyde in the urine, such as urotropin and helmitol. The latter is said to be preferable when the urine is alkaline. These drugs are most valuable as prophylactics where the catheter is frequently used. Before operating upon the bladder, and for a time afterwards, urotropin may be given in doses of 5 grains every eight hours. Of course, these substances do not kill any germs at all: they merely inhibit their growth in the urine.

Section V.—Disinfection of Hands.

If the general surface of the skin does not often contain microbes of high virulence, such is not quite the case with the hands, especially the hands of surgeons. The question of avoiding contamination of the hands by germs of high virulence has been previously discussed. I regard rubber gloves as the greatest advance in asepsis since the practice of boiling instruments and steaming dressings was introduced. By the use of them the surgeon can not only avoid contaminating his own hands with virulent germs, but in the case of his assistants infection by means of hands can be absolutely eliminated. Assistants at an operation should wear gloves. With a little practice it is not difficult even to thread needles whilst wearing them. But even if they should delay an operation for a few moments, the surgeon has no right to sacrifice the safety of the patient to his own impatience. Unfortunately, gloves impair the delicate sense of touch often needful to the surgeon; otherwise it would be advisable for him to wear them at all operations. In septic cases, however, the wide exposure of parts which is usual in such renders the seat of disease visible, and the manipulations are not often such as need very delicate touch.

If the surgeon in any particular case where sepsis is present considers it his duty not to wear gloves, he should not operate upon any aseptic case with bare hands for at least a week afterwards. This may seem superfluous ; even so great an authority as Schimmelbusch thought it was, but the cases quoted in the Appendix of this volume have quite convinced the writer to the contrary. The gloves are sterilized by boiling. They are easy to put on if the hands be first lathered with soap. The surgeon should avoid cracks, cuts, and sores on his hands as far as possible, and to this end should never put his hands into any antiseptic solution which he finds from experience irritates them and causes cracking or desquamation. Before performing an operation the finger-nails should be cut as short as possible, and it is perhaps needless to add that rings should be removed.

The cleansing of the hands is performed in much the same manner as that of the patient's skin, but as the hands secrete little grease, fat solvents may be omitted.

1. The hands are washed for about two minutes with soap and sterile water as hot as can be borne.

2. They are thoroughly, patiently, and systematically scrubbed for five minutes with a

sterile nail-brush, using soap and a fresh basin of sterile hot water.

3. They are scrubbed with Lockwood's biniodide spirit solution (1 in 1,000), applied by means of a gauze swab to every part of them systematically. This is done for two or three minutes.

4. They are rinsed with sterile water.

If during the operation the surgeon desires to wash the blood from his hands sterile water should be used. The disinfection should be carried up the wrists to well above the spot to which the coat-sleeves reach. Fairly long sleeves are preferable, and they should be fastened to the wrists with sterilized tape. This effectually prevents the exposure of any undisinfected skin of the forearm. It is needless to add that the coat itself should be sterilized. If the surgeon's hands be very dirty or greasy, it is a good plan to begin the sterilization by rubbing them with soft soap and sand which has been sterilized by boiling. If the surgeon finds that the biniodide spirit irritates his hands too much, and causes desquamation, he should use weaker solutions, or even plain methylated spirit instead. The spirit and the swab probably do more than the biniodide. For reasons pointed out when dealing with the subject of chemical antiseptics, it is

clear that these substances could not be of great value in the disinfection of hands. In the first place, they have great difficulty in penetrating to the germs, and, in the second, they cannot be applied for a sufficient length of time to have any certain effect. Many other good methods of preparing the hands have been proposed. The chief point to bear in mind is that the hands cannot be rendered really sterile by any, and that thoroughness and intelligence in the mechanical part of the process is the most important factor. When once the surgeon has disinfected his hands, and his assistants have donned rubber gloves, they should be careful not to touch any unsterilized article.

It has been assumed by some writers that because a minute piece of epidermis removed from the hand does not show a growth in culture medium the hand is sterile. No more absurd fallacy could be imagined. In the first place, the piece removed represents but the most insignificant fraction of the total area; in the second, it only represents the superficial layers of the skin. The hand is one of the most difficult parts of the body to clean, owing to the folds of skin at the root and sides of the nail.

A word concerning sterilized cotton or silk gloves may not be out of place here. These are obviously valueless for the purposes for

which rubber gloves are so indispensable. Nevertheless, they may be useful for handling dry objects, such as sterilized dressings.

We have seen that air is almost a negligible quantity as a source of infection, and that the patient's skin can be almost entirely prevented from becoming a source of danger. We have also seen that the assistants' hands can be rendered absolutely safe by the wearing of rubber gloves. In the succeeding pages it will be shown that every other object which comes into contact with the wound may be rendered absolutely sterile. The surgeon's hands alone are left as a source of infection. The knowledge that such is the case is likely to exercise a most healthy effect upon his mind. A realization of the fact that he has caused the death of every patient who dies of wound infection introduced from without, that he alone occasions almost every case of acute suppuration, and that practically all such cases are avoidable, will cause him to exercise the utmost care to avert these disasters, and will bring about a corresponding improvement in his results.

Section VI.—Sterilization of Instruments.

In the pre-antiseptic era instruments were doubtless even more than hands the agents whereby the most dreadful wound infection was carried from patient to patient. After being used for a case of acute osteomyelitis or cellulitis, instruments were cleansed in a more or less perfunctory manner, and straightway used to amputate a limb. It is, therefore, no matter for surprise that in hospitals the mortality from sepsis was absolutely appalling. Even in the early days of antiseptics, when a short application of carbolic acid was considered sufficient, hundreds were slain in this fashion. To-day we can with absolute certainty disinfect our instruments in a few minutes. The sterilization of metal instruments is exceedingly simple, and may be summed up in the three words *clean and boil*. For the purpose of cleansing all instruments which are in more than one piece should be made to take apart, so that the joints may be cleaned. They are first scrubbed with a nail-brush and soap, but instruments with keen edges, such as knives, are better cleaned with a swab than a brush. Instruments are boiled for ten minutes in $\frac{1}{2}$ per cent. solution of lysol, or, roughly speaking, a

teaspoonful to the pint. This prevents rusting, and blunts them less than soda. It is better not to boil knives, as it spoils their keenness. If they are clean and bright they do not need it. The blades should be wrapped in gauze, and just as the sterilizer is removed from the gas-ring they should be dropped into the boiling lysol solution. Five minutes in this is sufficient to sterilize them. Needles may be treated similarly after being stuck into a piece of lint. They are, however, best retained sharp and bright by being kept permanently in a jar of pure lysol. This is washed off by dipping the needle into hot sterile water before using it. The practice of putting instruments into a solution of antiseptic after they have been boiled is manifestly absurd. They should be placed in a sterile tray, or left in the wire basket in which they were boiled, and should be covered with a sterile towel until the surgeon is ready for them. After an operation instruments are simply scrubbed with soap and hot water if the operation has been an aseptic one. If the case has been septic they should all be boiled in lysol solution at once after washing. The needles are replaced in the lysol and the other instruments dried and put away, preferably in an air-tight case, which will lessen any chance of rusting. The lysol is added to

the boiling water, not because it is an antiseptic, but in order to prevent rusting.

Nail-brushes may be boiled with the instruments.

Any vessel may be used for boiling instruments, but the most convenient apparatus is that of Schimmelbusch, which contains a wire basket for them. A fish-kettle makes a fairly good substitute. Where these are lacking it is a good plan to wrap the instruments in a towel. A piece of string is tied round this, a loop being left whereby the instruments may be hooked out. The piece of soap used for washing septic instruments should be thrown away, or dipped in boiling water to dissolve off the outer layer.

Section VII.—Aseptic Lotions.

At an aseptic operation only two lotions are permissible. The ideal one is warm sterilized normal saline solution, but boiled water is that most used, and is practically of equal value—at any rate, for cleansing hands. Antiseptics are not only quite incapable of doing good, but are likely to do harm. They are incapable of killing germs in a wound, but are quite capable of killing or injuring tissues. Sterile water is made of the desired temperature by adding boiling water to cold water which has been

previously sterilized by boiling. Plenty of both should be prepared before an operation.

Section VIII.—Sterilization of Sponges.

The use of sponges has been largely superseded by that of pads of gauze or of cotton-wool sewn up in gauze. These can be sterilized by steam.

The following shows the difficulty of disinfecting sponges, and is also a valuable comment upon the unreliability of chemical antiseptics. Sponges were thoroughly washed and placed in a 1 in 500 solution of permanganate of potash. They were then bleached in a 10 per cent. solution of hyposulphite of sodium, to which was added 8 per cent. of pure hydrochloric acid. Then, after being rinsed in water, they were kept in a 5 per cent. solution of carbolic acid. Thus the sponges were exposed for some time to the action of four well-known antiseptics, yet Frisch found germs in 20 per cent. of them Schimmelbusch).

Schimmelbusch recommends that sponges should be put in a linen bag and entirely submerged in a solution of 1 per cent. of carbonate of soda at just below boiling-point, and left lying in it for half an hour whilst it gradually

cools. A large mass of soda solution should be used, so that it may cool slowly. He states that sponges saturated with anthrax spores and pus were sterilized by this method.

Section IX.—Sterilization of Dressings, etc.

Steam is used for the sterilization of these. The following are the essential points :

1. The goods should be clean and free from any kind of dirt or grease.
2. The steam chamber should maintain a temperature of 100° C. for fully forty minutes.
3. The steam should enter at the top of the chamber and leave it at the bottom.
4. The goods to be disinfected should not be too closely folded or too tightly packed.

Swabs are best made either of gauze or of cotton-wool sewn or tied up in gauze.

Dressings are made of various materials. The essentials of a good dressing are :

1. High power of absorption.
2. Permeability to air.
3. Freedom from germs.
4. Reasonableness in price.

The absorptive power of a dressing is necessarily of first importance, seeing that its function is to absorb discharges. Permeability to

air is essential in order to dry the discharges, and so deprive any germs which migh be present of the moisture which is essential to their growth. No germs can possibly grow in a *dried* discharge, so that impregnation of dressings with antiseptics only serves to irritate the skin of the patient. The third and fourth qualifications for a dressing are obvious. Yet with regard to the third it may be said that a sterile dressing outside the skin is of far less importance than a sterile wound beneath it.

Without doubt simple sterilized gauze is by far the best dressing for an aseptic wound. It absorbs serum or blood with great readiness, and permits them to dry with rapidity. The only objection to making the whole dressing of gauze is the expense. It is usual, therefore, to put gauze next to the wound, and to back it up with some cheaper material. For this purpose moss, cotton-wool, or tow are generally used. Pads of moss sewn up in gauze make an excellent dressing, being more absorbent, more elastic, and cooler than cotton-wool. They are easily sterilized by steam. If moss be not available or the situation be more suitable for wool, the latter may be used.

Pads of tow sewn up in gauze are sometimes employed on account of their cheapness when

very large quantities of discharge are present. They are cheap and easily sterilized, but their absorptive powers are limited.

Towels, aprons, linen coats, etc., are sterilized by steam. They must not be too tightly folded.

In an emergency where no proper dressings or appliances are at hand, boiled, or even scalded, linen may be used. For example, a strip torn off a sheet and boiled for a few minutes, or even scalded by pouring a considerable quantity of boiling water upon it, might be used to plug a wound or a uterus.

Section X.—Sterilization of Ligatures and Sutures.

The choice of material for ligatures is practically limited to silk and catgut, but for sutures many materials have been used. Silver wire, brass wire, silk, linen thread, silkworm gut, horsehair, catgut, and kangaroo tendon, are amongst those most frequently employed. Sutures may be either temporary or permanent. Temporary sutures are those which are intended to be removed by the surgeon after the wound has healed. Permanent sutures are those which are left in the wound, and are intended to finally become absorbed or encysted. For purposes

of asepsis they may be divided into three classes :

1. Those which may be easily sterilized by boiling, such as wire, silk, thread, or horsehair.

2. Those which may be sterilized by boiling, but with greater difficulty, such as silkworm gut or celluloid thread.

3. Those which cannot be boiled in water or steamed, such as catgut or kangaroo tendon. In the case of the first group sterilization is a very simple matter. They are boiled for fifteen minutes. Plain water must be used in the case of silk or horsehair, as boiling in alkali renders them brittle. After boiling they may be kept, if desired, in a 1 in 1,000 watery solution of biniodide.

The second class form an interesting group. They can be boiled without affecting their strength, but as they may contain germs, and as water does not penetrate them, the heat must be counted as dry heat, and continued for several hours. I have long been convinced on clinical grounds that fishing gut boiled for fifteen minutes was not sterile. Buried sutures of it proved far more liable to set up suppuration than those of silver wire or silk.

The third group are destroyed by boiling water or steam; therefore their sterilization is no easy matter. The difficulty of disinfecting

catgut may be gauged from the fact that over a hundred methods have been proposed. Catgut is made from the intestine of the sheep. As it comes from the manufacturer it abounds in germs. As it is made by a process of twisting, these germs are present in the centre as well as upon the surface. Moreover, the workman polishes it with oil rubbed in by hand. In catgut, therefore, to begin with we have an impermeable material containing germs in abundance throughout its entire thickness, which cannot from its nature be boiled or steamed. Lastly, as sheep are liable to anthrax, in rare cases the gut may have anthrax spores in it. Volkmann records cases of this disease which he believes were due to infection from catgut. We have also to consider the fact that gut which will not give rise to growth in ordinary culture media may nevertheless infect wounds. This was clearly shown by the experiments of Klemm, which have been mentioned previously. This failure in culture media was probably due to inhibition by chemicals in the gut, but it is also possible that the methods of culture used were unfavourable to the particular microbe present.

It is evident, then, that the absolute and certain sterilization of catgut affords no easy problem. Many surgeons, finding by experi-

ence that they are unable to obtain reliably sterile gut, have entirely abandoned its use. Nevertheless, an absorbable suture is certainly an advantage, for those which are not absorbed occasionally set up suppuration long after the wound has healed. The frequency of this has been exaggerated by some writers. In the vast majority of cases, when suppuration takes place within three weeks of operation the wound has been infected at the time of operation. In some cases, probably, catgut has been used with living microbes in the centre, which have been liberated during the disintegration of the gut. In other cases the infection is probably due to micro-organisms of low virulence from the skin. Certainly, buried sutures more often cause suppuration in situations such as the groin, where the skin is difficult to disinfect. These germs naturally are more liable to set up trouble when sutures have been tied too tightly and tissues killed by strangulation. Occasionally, however, buried sutures suppurate months after the operation. In this case microbes have perhaps been carried by the circulation, and have attacked the *locus resistentiæ minoris*.

Very many chemical methods of sterilizing catgut have been proposed. In all these the fat must be carefully removed from the gut, to allow the antiseptic to penetrate. One of the

best is Lockwood's. The gut is scrubbed with soap and water, soaked in ether for twenty-four hours to remove the fat, and then transferred to 1 in 250 watery solution of biniodide of mercury, in which it is left permanently. It should remain in this solution for at least three days before using. Biniodide spirit is preferable to watery solution, giving a better grip to the gut. It is better to have the gut cut into ligature lengths, or to wind it in a single layer, to facilitate penetration by the solution.

Heat can be used for sterilizing gut, and where reliable heat methods can be applied they are preferable to chemical methods. Chemicals have difficulty in penetrating, and cannot be relied upon to kill germs buried in organic matter, especially if spore-bearing bacilli happen to be amongst them. A method which will sterilize fifty samples of catgut may fail to sterilize the fifty-first, owing to the presence of highly-resistant spores. The great difficulty in sterilizing it by dry heat is due to the fact that it always contains water, and this combines with the gut to form gelatine when heat is applied. The first step is, therefore, to extract all the water. If this be completely done it can be subjected to very high temperatures. I have heated gut to 200° C. without injury.

It is said that the gut may be dried by

placing it in absolute alcohol, but I have found this method unreliable. The best method of drying gut is by heat. A heat of 80° C. for one hour, as recommended by Krönig, I have not found always sufficient, and therefore heat for two hours at 80° C.

To facilitate drying, the gut should be wound in a single layer, or made into small coils or figures of eight. It is difficult to dry properly if wound in several layers.

Reverdin used hot air to sterilize gut, but anyone who has worked with a hot-air apparatus knows the difficulty of accurately regulating the temperature. This is much more easily managed if the gut be immersed in some fluid medium. Various fluids have been recommended for this purpose, such as alcohol (Jellett), xylol (Brünner), and cumol (Krönig).

Although a fluid medium is used, as no water is present the heat must be counted as dry heat. It is therefore necessary that either a very high temperature should be employed or that the heat should be applied for a long time. Krönig heated the catgut in cumol for an hour at 80° C., and then for an hour at 160° C. The author has used creasote for the same purpose.

The apparatus required is very simple. The catgut is wound in a single layer, or made into small coils or figures of eight. For the purpose

of drying I have designed spools which consist of two hexagonal metal plates joined together by six metal rods. The plates are perforated at their centre by square holes, through which the shaft of a winder may be passed. They are also perforated at the margin by a small hole, through which the catgut is passed in order to tie it. The catgut is placed in a beaker, and immersed in cumol or creasote. The beaker is covered with a piece of stout cardboard perforated by a small hole, through which a Centigrade thermometer passes. The bulb of the thermometer is suspended in the liquid. The beaker is placed in a sand-bath, and heat applied by a Bunsen flame. The temperature is slowly raised to 80° C., and kept at that for two hours. The heat is then gradually increased until it reaches 160° C., at which it is maintained for an hour. The gut may be preserved in alcohol, ordinary methylated spirit being quite suitable for the purpose. Unless great care be used in the drying, failure will result. This process is applicable also to gut which has been hardened in chromic acid or formalin. I have found Morson's No. 2 quality creasote most suitable for the purpose.

It is an obvious advantage, however, to use a temperature of 100° C., for then a water-bath can be employed. This makes the regulation of heat

much more simple. Brünner found that in xylol at 100° C. anthrax spores were killed in less than three hours. It is evident, therefore, that heating to 100° C. for six hours should leave a margin for safety.

For this purpose I have designed an apparatus which has answered admirably. It consists of a water-bath which has a deep well, into which fits a wire basket. The lid of the well, which should fit accurately, has a small perforation to allow the steam from the catgut to escape. A hole in the upper surface of the apparatus allows a Centigrade thermometer to be suspended in the water, the thermometer passing through a perforated cork. A small steam escape is placed on one side, and a water-gauge on the opposite side. The apparatus is made of copper, and the sides are covered with asbestos packing. By reason of this packing and the comparatively large bulk of water, the temperature can be regulated with the greatest ease. The well is filled to the desired depth with turpentine, and the rest of the apparatus filled with water. This can be done by removing the cork through which the thermometer passes, and pouring in the water by means of a funnel. The catgut, which should be wound in a single layer on metal spools, or made into small coils, etc., is placed in the wire basket,

and this is lowered into the turpentine, and the lid of the well shut tightly. The temperature is then raised to 80° C., at which it is kept for two hours. The heat is then raised to 100° C., and the water boiled for at least six hours. When the process is completed the wire-basket is lifted out, and the gut is transferred to a jar of methylated spirit, in which it is kept permanently. This process is especially suited to chromic gut, which is not readily penetrated by chemicals. Turpentine is cheap, and easily obtainable; it is a good fat solvent, and has a boiling-point much above that of water. I do not know why its use has not been suggested as a medium for this purpose before. Xylol or creasote would, of course, do equally well. Useful, though not elegant, spools may be made from ordinary composition gas-piping, which can readily be cut into desired lengths with a knife. This process is an easy and reliable one, and gives excellent results.

Chromic gut takes much longer than ordinary gut to become absorbed in the tissues. Hence it should be used for buried sutures when it is desired that these should not be absorbed for several weeks. It may be readily disinfected in the same way as ordinary gut by the application of heat.

Catgut may also be hardened in formalin, after which it can be boiled in water. The process is as follows :

1. Wind on metal spools in a single layer.
2. Immerse in ether for twenty-four hours.
3. Immerse in 4 per cent. formalin for forty-eight to seventy-two hours, according to thickness of gut.
4. Wash in running water for twenty-four hours.
5. Boil in water for ten minutes.

It may be preserved in 1 in 1,000 solution of biniodide in methylated spirit.

Section XI.—Sterilization of Drainage Apparatus.

Much controversy has centred about the subject of drainage, which is one needing judgment on the part of the surgeon. In operation wounds drainage should be used :

1. Whenever the surgeon is in doubt about the efficacy of his asepsis.
2. Whenever spaces of any considerable size are left in the wound.
3. Whenever a considerable quantity of discharge is anticipated.

In all other cases drainage is superfluous, and sometimes injurious. It is advisable to drain

on account of the possibility of sepsis in many emergency cases where the skin cannot be properly prepared, also in cases of perforated gastric ulcer, in cases of cystotomy where the bladder is not aseptic, and in any case where the asepticity of the tissues is at all doubtful. Drainage should also be employed whenever spaces exist in the wound which cannot be obliterated by buried sutures or by firm pressure, as, for instance, after a major amputation. Lastly, it should be employed where much serous discharge is anticipated, as in the removal of lymphatic glands, where lymph pours into the wound from the cut lymph vessels.

Drainage of the abdomen should only be employed where some septic condition within the peritoneal cavity is present, or in some cases where the surgeon cannot be sure of effectually controlling hæmorrhage. In the case of the pelvis, drainage, when necessary, should be made through the posterior vaginal fornix. The drainage is more efficient, and the chance of a subsequent ventral hernia is lessened. In the case of the upper abdomen, drainage through the loin is equally useful. Where drainage is employed on account of a doubt as regards asepsis buried sutures should not be used. This is in accord with the great surgical principle—*if aseptic shut up, if septic keep open.* If

the operator has sufficient confidence in his asepsis to use buried sutures, he should also have sufficient to dispense with drainage. If any wound is sufficiently aseptic to allow deep sutures to heal in, drainage is superfluous; if it is septic, no drainage will save them. The ideal procedure is to obliterate the wound cavity by means of buried sutures. Not only should layer be stitched to corresponding layer, but occasionally the stitch should also include the layer below, so as to obviate any collection of blood between the strata. This ideal should never be attempted where any reasonable doubt exists with regard to asepsis.

The chief materials used for drains are rubber tubing, gauze, lamp-wick, and oiled silk. The latter is much preferable to gutta-percha tissue, as it can be boiled. A flat strip of oiled silk forms an excellent drain where discharge is only slight; it scarcely separates the sides of the wound, and yet prevents them from adhering. When it is lifted out they fall together. Gauze is very valuable as a packing for checking hæmorrhage, as well as for draining, and in highly septic wounds the whole wound cavity may with advantage be packed with it. A mere strip of gauze is of no use whatever to drain thick discharges such as pus. It only does harm by blocking the opening. On pulling

it out, a gush of pus will often follow. Lamp-wick is used to drain serous discharge in the same way as gauze. When the discharge is likely to be copious, a rubber drainage-tube should be used. It should likewise be employed where the discharge of blood or pus is expected. When the wound is highly septic, and when serious constitutional disturbance is present, it is better to leave the wound entirely open, and lightly stuff it with gauze.

Glass drainage-tubes are still preferred by some surgeons for the abdomen, but to drain a cavity *upwards* is somewhat unsatisfactory. Glass or rubber tubes and oiled silk are sterilized by boiling, as gauze and lamp-wick by steaming.

Section XII.—Secondary Dressings.

When a wound is expected to heal by first intention, the dressings should not, as a rule, be removed until the sixth day, unless local or general symptoms give rise to the suspicion that the wound is not pursuing an aseptic course. When such a suspicion exists, the wound should always be inspected at once.

It is advisable to look at the wound about the sixth day, because some invasion by organisms may have taken place about the stitches, and rendered the removal of some of

them desirable. For this reason the subcuticular stitch has decided advantages, and where it is employed no secondary dressings are necessary at all, as the primary one need not be disturbed for ten days. Occasionally the dressings will have to be changed within twenty-four hours after operation, either on account of excessive discharge or because of contamination of the dressings with urine or fæces. In this latter case, also, the subcuticular stitch is of advantage, for after the first few hours a collodion dressing is all that is needful. In the case of wounds about the mouth, where the dressings are liable to become soaked with saliva, it is often advisable to employ no dressing at all. A pad may be applied for the first few hours until hæmorrhage ceases. It is surprising how well they heal under the scab which forms.

The same precautions should be used in dressing a wound as are observed at operations, but the use of rubber gloves saves much time and trouble in preparing the hands, as well as preserving the hands of the dresser, which are liable to be irritated by incessant scrubbing.

The danger of infecting a wound at secondary dressings has been exaggerated. After forty-eight hours the difficulty of causing suppuration in a wound is much increased. The lymph

spaces have become sealed, exudation of leucocytes has taken place, and the connective-tissue cells have commenced to multiply. The resisting power of the tissues has therefore been much strengthened. Most cases of late suppuration in wounds are due to imperfectly-sterilized catgut, or to infection at the time of operation with germs of not very high virulence which are capable of causing pus formation in time, but incapable of causing acute symptoms.

Section XIII.—Operating Theatre and Furniture.

It is quite a mistake to suppose that any special room or furniture is necessary in order to obtain first-class results. Neither the theatre nor the furniture touches the wound, nor ought they to come into contact with any sterilized object which subsequently touches the wound. It is, however, an advantage to have a well-lighted and properly-equipped theatre. A well-built operation theatre should have a good light both from the roof and from at least one side. It should have no sharp angles or corners, in order to facilitate sweeping. There should be no ledges anywhere upon which dust may collect. Especially should this be insisted upon in the case of the skylight. The best material

for the walls is glazed tiles. For the floor sheet lead is preferable. It is superior to tiles in everything except appearance, being non-absorbent and impenetrable. The floor should be drained by open gutters having an appropriate gradient to facilitate flow along them. Such a floor permits of ready flushing with boiling water if necessary.

The operating-table is preferably made of metal, and a good mechanical table which permits changes of position to be made with a minimum of trouble and disturbance is a great advantage.

Basins are best made of enamelled iron, and should be placed loose in an iron stand, so that they can be taken out and boiled if necessary.

Taps are a common source of infection, both in operating-theatres and in wards. A person with pus on his fingers uses the tap, and another contaminates his hands thereby. Taps which are turned on with the foot are good, but a tap which is turned on with a key is equally safe if care be taken to drop the key into boiling water whenever necessary.

Instrument-cases should have shelves of some non-absorbent material, such as glass, but there is no necessity for the elaborate and expensive cases now in vogue, seeing that instruments are boiled before use.

Section XIV.—An Aseptic Operation.

The following description of an operation (Bassini) for the radical cure of inguinal hernia may serve to give concrete form to the principles which have been previously enunciated. We shall assume that the surgeon has two assistants, one of whom we shall designate aseptic, whose duty is to directly assist the surgeon. The other, who may be called the septic assistant, may be employed in moving the patient, arranging bed-clothes, assisting the anæsthetist, etc. These duties are usually assigned to a nurse. We shall assume that the patient's skin has been prepared, and a biniodide pad applied; that the surgeon has prepared his hands, and that the instruments, swabs, and dressings have been prepared as directed. The instruments are in the wire tray in which they have been boiled, the ligatures and sutures occupy a small sterile basin; both are covered with sterile towels. When the patient is properly under the influence of the anæsthetic the septic assistant lifts the patient's clothes nearly to the level of the umbilicus, and draws down the blankets below the level of the groin. She next places a piece of mackintosh over the clothes both above and below, and tucks the border of it beneath the clothes to a

depth of several inches. She then removes the bandage, but leaves the pad undisturbed. The surgeon and aseptic assistant now take their places on opposite sides of the patient, the surgeon having the instruments and the assistant the swabs within easy reach. The aseptic assistant, who wears rubber gloves, next takes two sterile towels and covers the mackintosh with them, taking care not to touch the mackintosh or the patient's skin in doing so; they should overlap the biniodide pad. The surgeon now turns to the anæsthetist and inquires whether the patient is sufficiently anæsthetized. If the answer be in the affirmative he takes up a pair of sterile forceps, and with it removes the pad. This pair of forceps is then discarded, as the outside of the dressing may have been contaminated by the septic assistant. The aseptic assistant then draws the sterile towels up to about an inch from the site of incision. The surgeon now makes his incision through skin and superficial fascia down to the aponeurosis, and stops any bleeding vessels by tying or twisting. He now takes two sterile napkins and stitches one to each skin edge, and pins them together beyond the ends of the wound with sterile safety-pins. A continuous stitch with wide intervals is used for each side. In this way the patient's skin is effectually shut

off from contact with anything which afterwards touches the wound. The surgeon now incises the aponeurosis of the external oblique, and separates it from the internal oblique for some distance upwards and downwards. He next defines the deep shelving portion of Poupart's ligament. The sac is now separated from the cord and removed. This is easily done by the fingers, aided by an occasional touch with the forceps, if the separation be commenced near the upper end of the sac. Tearing the tissues should be avoided as far as can be done. There is no need to separate the lower portion of the sac if it is large. It can be left behind with far less chance of giving trouble than the oozing of blood caused by its removal. It is necessary to remove all that part which occupies the canal, and to tie the upper end flush with the general peritoneal surface. No dimple should be left. In doing this it is not necessary to cut any fibres of the internal oblique; gentle stretching will suffice. The sac is transfixed before tying, for which purpose No. 2 catgut may be used. All bleeding-points are next carefully picked up and ligatured. The surgeon now inserts from four to six interrupted sutures between the lower border of the internal oblique and the shelving part of Poupart's ligament; these sutures pass

beneath the cord. No. 2 chromic gut is large enough for these. The aponeurosis of the external oblique is stitched over the cord with a continuous suture of No. 0 chromic gut. This is quite strong enough, as the aponeurosis is divided parallel to its fibres. The stitches which hold the napkins to the skin are now removed, but the safety-pins are left in position, and the napkins retracted no further than is necessary. The subcutaneous tissue is now stitched with a continuous suture of No. 0 catgut, which here and there dips down and includes a few fibres of the aponeurosis beneath. The skin is stitched with a subcuticular suture of No. 0 catgut, care being taken to insure accurate apposition. The skin is wiped with a sterile swab. It need not be washed, as one is liable, if not very careful, to let water run over the wound from an undisinfected part. A little sterile dry blood is harmless. The wound is now covered with about half a dozen layers of sterile gauze cut large enough to overlap it for about 2 inches in every direction. This is held in position by the surgeon while the assistant cleans the skin where blood has run over it, but keeps the cleansing operations wide of the wound. A sterile pad is now placed over the gauze; it is made of cotton-wool or moss sewn up in gauze. This is fixed on by means of a

broad piece of strapping. No spica or other bandage is necessary. The operation occupies a little over half an hour with an operator of average dexterity, and the wound will almost invariably heal by first intention if the above directions be faithfully carried out, and the surgeon has avoided virulent hand contamination from previous septic cases. If he has not done so, the result may prove disastrous, in spite of every other precaution.

PART IV

THE TREATMENT OF SEPTIC WOUNDS

A SEPTIC wound does not simply mean a wound in which living germs are present. As has been previously pointed out, living germs are left in most, if not in all, wounds. After a properly-conducted aseptic operation these few organisms are quickly killed by the tissues. By a septic wound is meant one in which the organisms are multiplying and attacking the tissues. The word originally meant putrefaction, but in surgery it no longer bears this meaning. The commoner infective processes in wounds may be roughly divided into four classes :

1. Fulminating sepsis.
2. Acute cellulitis.
3. Acute suppuration.
4. Asthenic suppuration.

I have used the word 'asthenic' as the term 'chronic' is hardly applicable to wound infection. This classification is not a highly scientific one.

It makes no provision for the kind of organism setting up the process, but for practical purposes the species of microbe is of less importance than its virulence. The classification will be found a useful one with regard to treatment. The great principle to be followed in dealing with septic wounds is to be found in the axiom, *If septic, shut up; if aseptic, keep open*, and its corollary, *The more septic, the more open.*

The fulminating cases of wound infection are sometimes of incredible severity. There may be practically no tissue reaction at all. In such cases death may be wrongly attributed to shock, especially when the peritoneum has been infected. The symptoms are those of severe vital depression, such as pallor, rapid pulse, sweating, and increasing coldness of the extremities. The pulse constantly increases in rapidity, finally becoming uncountable, and then imperceptible. Death may result within forty-eight hours of operation. The temperature may be normal or subnormal, or it may be raised, but seldom becomes very high. Occasionally, however, even in these rapidly fatal cases, it rises to a considerable height. As previously stated, there is sometimes no reaction at all in the wound. At others it shows more or less inflammatory reaction, but death takes place before this has much time to develop.

ERRATUM.

Page 74, line 8, *should read*: "If aseptic, shut up; if septic, keep open."

Another type of acute sepsis gives rise to a rapidly-spreading cellulitis. In these cases serious symptoms do not set in until after twenty-four hours or more, the most usual interval being about thirty-six hours. The fever often does not reach any great height, but the pulse rises rapidly and continuously. Septic rashes in the form of erythema and urticaria are not infrequent. The patient feels ill and miserable, though towards the end this depression is sometimes replaced by an extraordinary hopefulness. Sweating is common, and frequently there is a peculiar unpleasant smell in the breath, sometimes described as sweet. The patient retains his mental faculties remarkably, and is sometimes clear in this respect almost to the moment of death. The wound shows a spreading flush of a more or less dusky hue, and discharges a thin turbid serum. The tissues in the wound and those around it are sodden and œdematous. Death usually takes place from five to seven days after operation. Sometimes, however, these cases may end in recovery after prompt opening and packing of the wound. The condition is due to infection with a virulent strain of streptococcus. I believe that these dangerous cases are almost always, if not invariably, due to germs carried from a previous case of acute

tissue infection by instruments or hands. The treatment consists in completely opening up the wound, and packing every part of it with sterile gauze. For this purpose every stitch should be removed, and the sides of the wound separated throughout its entire extent. The gauze should not be tightly packed, as is done to stop hæmorrhage, but nevertheless should occupy every part of the wound. It should be changed frequently, at first not less often than every six hours. No antiseptic lotion should be applied. It damages the tissues, but is quite harmless to the microbes buried in them. It is unnecessary and even harmful to wash the wound at all. Frequent change of dressings prevents decomposition of the discharges. The patient's strength should be kept up by judicious and frequent feeding. Milk and eggs are especially valuable. Tonic drugs, such as strychnine and quinine, may be given, and also stimulants ; but whether they or the drugs do much good is doubtful. However, giving them comforts the friends of the patient, who expect such treatment to be adopted. It is only fair to state that some authorities recommend large quantities of alcohol, and attach great importance to this method of treatment. Quinine in large doses is harmful, as it is liable to upset the stomach, and feeding is certainly

of paramount importance. In cases of cellulitis antistreptococcic serum may prove to be of value. At present the most contradictory reports have been published with regard to its efficacy, but it is certainly our duty to give the patient every chance which science may offer. However skilful the treatment, these cases usually die if the wound be a large one. Fortunately, since the invention of rubber gloves, they may be practically banished from surgery. It is needless to add that rubber gloves should always be worn when touching such a case. They should be dropped immediately afterwards into boiling water, and boiled for ten minutes in a closed vessel.

The acute localized suppuration of wounds is usually due to staphylococcus, especially the variety aureus. It is characterized by the classical symptoms of inflammation and the formation of so-called laudable pus, and usually ends in recovery. The symptoms as a rule begin on the third day after the infliction of a wound. The constitutional symptoms are chiefly characterized by fever, and its accompanying malaise, headache, thirst, scanty and high-coloured urine, furred tongue, and so on. Rigors may occur if the infection be severe. If the temperature does not fall to normal within a period of forty-eight hours after opera-

tion, the wound should always be inspected. Fever following the infliction of a wound does not necessarily indicate that septic trouble is taking place. The temperature frequently rises within a few hours after operation, but falls again within twenty-four hours or so from the time of its rise, and the wound heals by first intention. This is called reactionary or simple traumatic fever. Its cause is not accurately known. Various hypotheses have been advanced, such as nervous disturbance, absorption of fibrin ferment, or of nucleo-albumin, or what not, from the injured tissues. Two facts, however, are certain—one is that such fever is much less common in subcutaneous injuries, such as simple fractures, than in surgical wounds. The other is that with the perfection of aseptic technique this fever tends to become less in frequency and severity. These facts suggest that it may be due to toxins absorbed from organisms which have been killed by the tissues. It does, however, sometimes occur in simple fractures, and may perhaps be due to more than one cause.

In any case of doubt it is always advisable to inspect the wound. This, as a rule, shows the nature of the fever. When suppuration is about to take place the margin of the wound shows a red flush, extending to a variable

distance from the incision. There is some swelling, and œdema may be present if the inflammation is severe. The wound is tender to the touch, and gives rise to more or less pain, usually of a throbbing character.

The treatment of these wounds varies with the severity of the local reaction and the amount of constitutional disturbance present. Where these are severe it is better to open up the wound and pack it with gauze. Frequently, however, the symptoms are less acute, and such radical treatment is not necessary. It may only be needful to pass a director to the depth of the wound at one spot, and insert a drain-tube. Sometimes one part of a wound will heal by first intention, whilst another part suppurates. After inserting a drain it will often be found of advantage to apply hot boracic fomentations. It has become the fashion rather to despise these applications, but they are comforting to the patient, and do not stick to the wound. The strength should be about 3 per cent. They should be as hot as can be borne, and should be changed every few hours. The object of the boracic acid is to prevent saprophytes from growing in the pus which has been absorbed by the fomentation, and causing it to become offensive. When the discharge diminishes and the inflammation dis-

appears these may be discontinued, and a dry dressing applied. It may be stated as a general law that the later the date at which inflammation appears in a wound the less will be the local and constitutional reaction. An exception to this rule occurs in the case of certain specific wound infections, such as tetanus.

Stitch abscesses are usually the result of tying stitches too tightly, or of imperfect skin disinfection. They may be present when the wound itself heals by first intention, and afford a valuable illustration of the importance of conserving tissue vitality. Organisms have not been present in sufficient number or of sufficient virulence to attack the tissues in the wound, but nevertheless they have been quite capable of invading those which have been strangulated by the suture. In some cases the stitch has not been sterile, though probably in most it has been quite aseptic, but the stitch track has been invaded by organisms from the patient's skin.

The term 'asthenic suppuration' may be applied to those cases where the wound appears to heal by first intention, and then after a variable period, usually from one to three weeks after operation, a part of it breaks down and discharges pus. There is little reaction in the wound, and no constitutional symptoms are present. Suppuration of this kind, as a rule, takes place in connection with deep sutures,

and where these are not of an absorbable nature it usually continues until they are extruded. It is sometimes due to organisms contained in the sutures themselves. This is especially the case with catgut and fishing-gut. It is, however, I believe, more often due to contamination of sutures by the patient's skin or the surgeon's fingers. If the surgeon eliminate the patient's skin in the manner previously described, and avoid touching with his hands that part of the suture which is left in the wound, he will be little troubled with suppuration of this kind. Chromic gut has the advantage that when this class of suppuration takes place the suture will nevertheless be absorbed, and its removal will not often become necessary. It has, however, the disadvantage of being far harder to sterilize than silk. The surgeon will perhaps be wiser to use silk which he himself has boiled than to trust to a manufacturer to sterilize chromic gut for him. The only treatment necessary in these cases is to remove the buried suture or sutures if these are not discharged within a reasonable time.

In dressing a septic wound aseptic precautions should be observed. This sounds paradoxical, but it is nevertheless of importance. The introduction of a fresh variety of microbe may increase the virulence of the infection.

PART V

THE TREATMENT OF ACCIDENTAL WOUNDS

The treatment of accidental wounds requires judgment on the part of the surgeon. It is often most difficult to decide upon the best method of treatment to adopt. All accidental wounds are contaminated when the surgeon sees them, and the skin around them abounds in bacteria. In considering this problem the surgeon should bear in mind the three factors which determine wound infection—viz., tissue resistance, the number of germs likely to be present, and, lastly, their probable virulence. Of the first two he can often make a fair estimate, but with regard to the latter he stands on more doubtful ground. With regard to tissue vitality, both local and general factors should be taken into consideration. One would rightly hesitate to stitch up a scalp wound in a chronic drunkard in a case where it might be right practice to do so in a healthy and tem-

perate person. Again, the region is of importance. Scalp and face wounds heal with remarkable readiness; those of the foot often do badly in this respect. The most important factors, however, are the local ones, and the surgeon in any given case usually considers chiefly the nature of the wound, and the amount and kind of dirt likely to have entered it. If the wound is irregular, ragged, or contused, no serious attempt should be made to close it. An odd stitch or two, however, combined with drainage, may be sometimes justifiable. Where gross dirt has entered a wound stitching had better not be attempted, but a good deal depends upon the kind of dirt. Garden mould, for example, often contains most dangerous microbes, whereas the black greasy dirt upon the hands of an engineer will probably contain nothing harmful at all. The length of time which has elapsed since the infliction of a wound is also of importance, for the longer it has been done the more chance will any germs in it have had to multiply. A wound which has bled freely will be more likely to be clean than one which has bled little, for the flow of blood will cleanse the tissue more effectually than any efforts of the surgeon. It is better, if possible, to avoid washing the surface of an accidental wound. Our efforts, as a rule, wash in more germs from

the patient's skin than they wash out of the wounded tissue. If, however, the wound have gross dirt in it this will be necessary. If washing is done at all, it must be done thoroughly, or it will do more harm than good. If there be no gross dirt in the wound the raw surface should be wiped with sterile gauze. The wound is then temporarily plugged with a piece of gauze, whilst the skin edges are cleaned with swabs of gauze or cotton-wool wrung out with methylated spirit, to which biniodide may be added if the surgeon desires. This wiping should always be made from the wound, and not towards it. The swabs should not be wet enough for the fluid to be squeezed out of them in the process, and so enter the wound. If the wound be superficial, especially if it be on the face, it may then be completely stitched up. In the case of any wound of the face, if possible an effort should be made to secure accurate union, as the scar is much diminished thereby. The exceptional healing power of this region usually causes healing by first intention to take place. If an incised wound be a clean one, but deep, it is better to stitch it, and to insert a drain into its deepest part. Punctured wounds, however clean, should be drained from the bottom, even if they have to be enlarged in order to do this. If the wound be clean, but

irregular or contused, it is advisable to plug it with gauze, at any rate in part, though sometimes a certain amount of stitching is justifiable. When a wound contains gross dirt, especially of the nature of garden soil, a determined effort should be made to clean it out. For this purpose it is advisable to administer an anæsthetic if the wound is a large one. The wound is thoroughly washed out with sterile water, the raw surface being scrubbed with swabs, or even a nail-brush if necessary. All loose tags are cut away, and if at any place the dirt cannot be removed the tissues containing it should be cut away with scissors. No particle of visible dirt should be left in the wound. The skin around the wound should also be well cleansed. If the wound be very deep it should then be plugged with sterile gauze throughout its entire extent, but in some more superficial wounds it may sometimes be justifiable to insert a few skin sutures. This, however, should be done with caution, because some of the most dangerous microbes found in soil are anaerobes, and hence the free access of air to all parts of the wound is desirable. In some of these cases secondary suture may be attempted. If after being plugged for forty-eight hours the wound surface looks clean and healthy it may be drawn together by means of sutures, and thus time

may be saved in the process of healing. Whatever treatment be adopted, accidental wounds should be inspected every day for four days. This precaution may save serious consequences where the wound is closed by suture. Where plugging is adopted this may not need removing for two days. After this time the wound may be replugged, left open, or sutured, according to its appearance. It is not easy to lay down very exact rules with regard to the treatment of accidental wounds. The surgeon must to a large extent rely upon his knowledge and experience. Those who have not had much experience will do well in cases of doubt to avoid closing the wound.

APPENDIX A

WOUND INFECTION FROM CATGUT

About two years ago I had occasion to operate upon an ovarian cyst, an inguinal hernia, and a varicose internal saphenous vein. In each operation a certain amount of No. 0 catgut was used from the same reel. The catgut was alleged to be aseptic by a well-known firm of manufacturers. I operated upon the hernia and vein upon the same day. The abdominal section was performed two days later. The cyst proved to be extensively adherent, and much catgut in the form of ligatures was left in the abdomen. The subsequent course of the three cases was as follows: The patient upon whom the abdominal section had been performed was in excellent condition the next morning. The temperature was normal, and the bowels acted after enema. On the third day symptoms of peritonitis appeared, and the patient died of purulent peritonitis on the sixth

day. In the case of inguinal hernia the superficial stitches of No. 0 catgut suppurated, but fortunately the deep sutures of chromic gut healed in, thus showing that the wound itself had not been infected. The varicose vein was only ligatured in one place. I removed the dressing on the fifth day, expecting to find the wound healed. The skin had adhered, and the single horsehair stitch had set up no irritation. As the skin was red, however, I pulled open the wound, and found that a small abscess had formed around the ligature. Unfortunately, the reel of catgut had been put back amongst a number of others, and could not be traced. Even had a bacteriological examination proved negative, it would not have shaken my conviction that the gut had caused the infection; the clinical evidence was too convincing. Since that time I have avoided trusting to any manufacturer to supply sterile catgut.

APPENDIX B

CASES OF INFECTION CONVEYED BY HAND

Case I.—In July, 1901, I had occasion to operate upon a fracture of the lower end of the humerus involving the elbow-joint. As the arm could not be got into a satisfactory position, I wired the fragments. Thirty-six hours after operation the temperature commenced to rise, and four hours later stood at 101° F. The next morning it had fallen to 100° F., but as the patient was far from well I inspected the wound. It was swollen and a little dusky, and discharging blood-stained, turbid serum. I had the patient anæsthetized, removed the wire and all the sutures, and packed the wound. The next morning the temperature was normal, but the patient's general condition was still unsatisfactory, and the pulse 104. On the following day the temperature was 99·4° F., pulse 112. Erythematous rashes appeared, and the patient was obviously in a dangerous condition. In the

evening the temperature was 100° F., pulse 105. The next evening the temperature was 103° F., and pulse 132, and the arm very swollen and œdematous. The patient became steadily worse, and died a week after operation. The case was one of cellulitis. I afterwards discovered that the matron had dressed a case of acute cellulitis before assisting at the operation. She had thought it no harm, as the inflammation had departed and the incisions were healing. She prepared her hands before operation by Lockwood's method.

Case II.—In July, 1902, I operated upon a case of acute osteomyelitis of the tibia. A coverslip preparation of the pus showed numbers of large staphylococci arranged in small groups. A month afterwards I operated upon a case of intussusception in an infant aged eight months. The matron who assisted me had on that day dressed the tibia, which was still discharging pus. Knowing the danger of infection, I saw that she took special pains to prepare her hands very thoroughly. Lockwood's method was used. Next morning the child was very well; the bowels had been opened naturally, and he was taking the breast with avidity. Temperature and pulse were normal. Forty hours after operation the temperature began to rise, and symptoms of peritonitis commenced to manifest

themselves. The child died five days after operation. The peritoneum was full of turbid serum. A coverslip preparation showed large staphylococci, which formed small groups. They were, in fact, morphologically identical with those found in the case of osteomyelitis. They were present apparently in pure culture. In this case the exact source of infection was evident, and it was clearly demonstrated that the most careful preparation of the hands could not be relied upon to disinfect them.

In both of these cases disaster could have been easily avoided by the use of rubber gloves. Since we have adopted the use of these we have never hesitated to operate even when the assistant's hands have been lately contaminated by virulent pus. On one occasion the matron assisted me at an operation for radical cure of femoral hernia whilst she had a suppurating sore upon her finger. Rubber gloves were used, and the wound healed by first intention, the patient's highest temperature after operation being 99° F.

The most virulent case of wound infection I ever saw was in a case of suprapubic lithotomy. The surgeon some hours previously had performed tracheotomy upon a case of diphtheria in which the throat had been in a highly septic

condition. The patient died three days after the lithotomy. This case, however, is of less importance than the others, because it occurred ten years ago, when surgeons had much faith in the disinfectant powers of perchloride of mercury, and did not appreciate the great difficulty of cleansing the hands. It was thought that dipping them for half a minute in perchloride lotion sufficed to kill all the germs upon them.

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THE END

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